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Industrial Pollution in Economic Development

(Kuznets Revisited)

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Industrial water pollution stabilizes with economic development, but there is no evidence that it declines.

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Summary findings

Using new international data, Hettige, Mani, and Wheeler test for an inverse U-shaped, or "Kuznets," relationship between industrial water pollution and economic development. They measure the effect of income growth on three proximate determinants of pollution: the share of manufacturing in total output, the sectoral composition of manufacturing, and the intensity (per unit of output) of industrial pollution at the "end of pipe."

They find that the manufacturing share of output follows a Kuznets-type trajectory, but the other two determinants do not.

Sectoral composition gets "cleaner" through middle-income status and then stabilizes.

At the end of pipe, pollution intensity declines strongly with income. The authors attribute this partly to stricter regulation as income increases and partly to pollution-labor complementarity in production.

When they combine the three relationships, they do not find a Kuznets relationship. Instead, total industrial water pollution rises rapidly through middle-income status and remains roughly constant thereafter.

To explore the implications of their findings, the authors simulate recent trends in industrial water pollution for industrial economies in the OECD, the newly industrialized countries, Asian developing countries, and ex-COMECON economies. They find roughly stable emissions in the OECD and ex-COMECON economies, moderate increases in the newly industrialized countries, and rapidly growing pollution in the Asian developing countries.

Their estimates for the 1980s suggest that Asian developing countries displaced the OECD economies as the greatest generators of industrial water pollution. Generally, however, the negative feedback from economic development to pollution intensity was sufficient to hold total world pollution growth to about 15 percent over the 12-year sample period.

This paper — a product of the Development Research Group — is part of a larger effort in the group to understand the economics of industrial pollution control in developing countries. The study was funded by the Research Support Budget under the research project "The Economics of Industrial Pollution Control in Developing Countries" (RPO 680-20). Copies of this paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact David Wheeler, room MC2-529, telephone 202-473-3401, fax 202-522-3230, Internet address dwheeler1@worldbank.org. January 1998. (36 pages)

INDUSTRIAL POLLUTION IN ECONOMIC DEVELOPMENT: KUZNETS REVISITED

by

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1. INTRODUCTION

A number of recent studies have explored the relationship between economic development and environmental quality. Theoretical papers by Gruver (1976), John and Pecchenino (1992), and Seldon and Song (1995) have derived transition paths for pollution, abatement effort and development under alternative assumptions about social welfare functions, pollution damage, the cost of abatement, and the productivity of capital. Empirical studies (Hettige, et. al. (1992), Shafik (1994), Seldon and Song (1994) and Grossman and Krueger (1995)) have searched for systematic relationships by regressing cross-country measures of ambient air and water quality on various polynomial specifications of income per capita. This extensive body of work has been motivated by several related questions: Does pollution follow a 'Kuznets' curve, first rising and then falling as income increases? At what income level does the turnaround occur? Do all pollutants follow the same trajectory? Is pollution reduction in developed economies due primarily to structural change, or to regulation?

The theoretical work has shown that a Kuznets, or inverted-U, relationship can result if a few plausible conditions are satisfied as income increases: Constant or falling marginal utility of consumption; rising marginal disutility of pollution; constant or rising marginal pollution damage; and rising marginal abatement cost. Of course, actual turnaround points depend on the relative magnitudes of the underlying parameters, as well as their signs. Although they are not explicitly captured by the theoretical models, structural change in the economy and more effective regulation are also potentially-important sources of change in pollution.

The empirical results are roughly consistent with a Kuznets curve for conventional air pollutants such as suspended particulates and sulphur dioxide, but the results for water pollution are mixed. In most cases, however, the implied trajectories are sensitive to inclusion of higherorder polynomial terms in income whose significance varies widely. Structural interpretation of the estimates remains ad hoc, since the existing studies have incorporated almost no evidence about actual emissions in developing countries.[1]

This paper attempts to advance the state of the art, using new data on industrial water emissions in developed and developing countries. Our analysis decomposes total industrial pollution into four proximate determinants: National output; the share of industry in national output; the share of polluting sectors in industrial output; and end-of-pipe pollution intensities in the polluting sectors. As most of the previously-cited work has noted (without being able to resolve the issue), declining pollution at higher levels of development must be driven by some combination of income-related changes in the latter three factors.

We investigate these changes in three econometric exercises. Using international panel data, we estimate the effects of economic development on industry's share of total output and the industry share of polluting sectors. To study development-related changes in end-of-pipe pollution intensity, we have collected factory-level data on industrial water pollution from national and regional environmental protection agencies (EPA's) in twelve countries: Brazil, China, Finland, India, Indonesia, Korea, Mexico, Netherlands, Philippines, Sri Lanka, Taiwan (China), Thailand and the US. Controlling for sectoral differences, we use these data to investigate the effects of income per capita, regulatory strictness and relative input prices on factory-level pollution intensity (pollution/output). In a complementary exercise, we add a measure of regulatory strictness to a cross-country labor intensity equation to test for the impact of regulation

[1] A partial exception is the work of Seldon and Song (1994), whose regressions employ air emissions instead of ambient air quality measures. The lack of monitoring information forces the authors to estimate air emissions from secondary sources: National fuel use data and fuel-based pollution parameters which are adjusted for conditions in countries at varying income levels. Data scarcity in developing countries is clearly

on the demand for labor. For our international pollution accounting exercise, these results provide two inputs: A measure of average water pollution intensity for each industry sector (an input to our study of income-related changes in polluting sectors), and an estimate of the change in sectoral pollution intensities as income per capita increases.

We combine our econometric results to simulate the total effect of economic development on industrial water pollution. In this case, we do not find an overall inverse U-shaped relationship. The three factors have very different relationships with income, and their joint product with total output is asymptotic, not parabolic. Industrial water emissions rise until countries attain middle-income status, and then remain approximately constant as they grow richer.

While our results do not support the Kuznets hypothesis for industrial water pollution, they do reveal a striking regularity in cross-country environmental performance. Our plant-level results suggest that pollution and labor intensities with respect to output decline continuously, and at almost exactly the same rate, as income increases. *Thus, sectoral pollution/labor ratios remain approximately constant during the development process.* This finding provides useful leverage for the analysis of pollution trends across countries and over time. As an illustration, we combine our estimated sectoral pollution/labor ratios with panel data on sectoral employment to simulate international trends in industrial water pollution during the past two decades.

The remainder of the paper is organized as follows. Section 2 develops the models which link our three pollution factors to economic development. Section 3 introduces the data used for estimation. Section 4 discusses the results and their implications, while Section 5 provides

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a problem for this exercise. Of thirty countries in the estimation sample only four (China, India, Thailand, Turkey) are LDC's.

illustrative estimates of recent water pollution trends in a number of developed and developing countries. Section 6 concludes the paper.

2. DEVELOPMENT AND INDUSTRIAL POLLUTION

The first stages of economic development typically witness the rapid growth of industrial activity and declining environmental quality in densely-populated urban areas. When new industries are pollution-intensive, their emissions can increase local ambient pollutant concentrations to harmful levels. To study this phenomenon, we decompose total industrial emissions in a particular region as follows.

(1) $P = m(y)Q\rho(y)\eta(y)$

where

P = Total industrial pollution
m = Manufacturing share of total output
Q = Total output
ρ = Manufacturing pollution intensity
η = Degree of pollution abatement: $0 < \eta \leq 1$
y = Income per capita

Equation (1) includes three parameters which we hypothesize to be functions of economic development: The manufacturing share of total output (m), the pollution intensity of manufacturing (ρ), and the degree of pollution abatement by industry (η). In this decomposition, the effect of economic development on pollution depends on the signs and the magnitudes of the parameters governing the relations between m, ρ, η and y.

2.1 Manufacturing Share of Total Output

Numerous studies of the relationship between industrialization and economic development have suggested an inverted-U relationship between the manufacturing share of output (m) and income per capita (y).[2] During the first phase of economic growth, *m* increases as industry expands more rapidly than agriculture. As the economy begins to mature, rapid growth in services becomes the dominant factor and *m* declines. Over the existing range of national incomes per capita, this relationship can be approximated with a parabolic function:

$$(2)\ \log m = \alpha_0 + \alpha_1 \log y + \alpha_2 (\log y)^2 \ (\alpha_1 > 0,\ \alpha_2 < 0)$$

Our empirical analysis uses cross-country evidence for the past two decades to estimate this relationship and test its intertemporal stability. We focus particularly on changes in $\delta m/\delta y$ as development proceeds. Controlling for growth in total output, large movements in *m* will have a significant impact on the trajectory followed by industrial pollution.

2.2 Sector-Weighted Pollution Intensity

The sectoral composition of industrial activity has an important effect on its average pollution intensity, or pollution per unit of output. Industrial processes differ greatly in their production of waste residuals which, in turn, have varying potential for creating environmental damage. Abatement costs also differ significantly by industry sector (Dasgupta, et. al. (1996), Hartman, et. al., (1997)). Even in well-regulated economies, these factors cause significant intersectoral differences in pollution intensity. For example, metals and cement are generally intensive in harmful air pollutants; food and paper production are disproportionate emitters of organic water pollutants (Hettige, et. al. (1995)).

Anecdotal evidence suggests that the sectoral composition of industry follows a 'clean' trend as development proceeds. This could reflect domination of early industrialization by primary industries, which generate heavy pollution loads as they convert bulk raw materials into primary

[2] For a discussion of structural change in development, see Syrquin (1989).

inputs (e.g. metals, paper, cement, sugar). During the development process, primary industries may lose output share to cleaner industries (e.g. vehicle and electronics assembly, instruments).[3] In this paper, we test the clean trend hypothesis for industrial water pollution by fitting the following equation to an international panel dataset:

$$\tilde{\rho}_{jt} = \beta_0 + \beta_1 \log y_{jt} + \beta_2 (\log y_{jt})^2$$

(3) *where*

$$\tilde{\rho} = \sum_k s_k \hat{\rho}_k$$

j, k, t = Country, sector and year respectively

$\hat{\rho}_j$ = Average pollution intensity for sector j (see Section 4.3)

2.3 Pollution Abatement

The marginal cost of abating pollution from industrial sources is a function of the scale of activity, pollutant concentration in process influent,[4] the degree of abatement, and local input prices.[5] In static partial equilibrium, cost-minimizing firms with flexible abatement choices will control pollution to the point where their marginal abatement costs equal the 'price' exacted for pollution by affected parties.[6] Characteristic production scale and process effluent intensity differ

[3] See Mani and Wheeler (1997) for further discussion.

[4] 'Influent' refers to emissions from industrial processes before treatment (or abatement); 'effluent' refers to emissions to air, water or land after treatment; 'concentration' refers to the quantity of pollutant per unit volume of the waste stream.

[5] For recent empirical evidence, see Hartman, et. al. (1997) and Dasgupta, et. al. (1996).

[6] These may, according to the circumstances, include local administrators, pressure groups, national regulators, stockholders, and 'green consumers.' Each group is in a position to impose some cost on a firm or plant if its emissions exceed the norms adopted by that group. Thus, even where pollution charges are in effect, there is no single 'price' of pollution. For a detailed discussion, see Afsah, et. al. (1996).

significantly by sector, and abatement costs differ by location. Differences in the groups affected by pollution can also lead to significant spatial variation in emissions prices.[7]

2.3.1 Pollution, Employment, Regulation and Input Prices

Where the environment is 'cheaper' or abatement is more expensive, the pollution intensity of production in a particular sector should be higher, ceteris paribus. However, data scarcity has made it difficult to test the magnitude of these effects, as well as the impact of spatial variation in the prices of capital, labor, energy and materials. At present, we have sufficient data to investigate these relationships in a two-equation demand system:[8]

$$
\begin{aligned}
\ln P_j &= \alpha_0 + \sum_S \delta_{SP} D_{SP} + \alpha_R \ln R_j + \alpha_K \ln W_{K_j} + \alpha_L \ln W_{L_j} + \alpha_E \ln W_{E_j} + \alpha_M \ln W_{M_j} + \alpha_Q \ln Q_j \\
\ln L_j &= \beta_0 + \sum_S \beta_{SL} D_{SL} + \beta_P \ln R_j + \beta_K \ln W_{K_j} + \beta_L \ln W_{L_j} + \beta_E \ln W_{E_j} + \beta_M \ln W_{M_j} + \beta_Q \ln Q_j
\end{aligned} \tag{4}
$$

where (for country j)

P = Plant-level pollution
L = Plant-level employment
D = Vector of dummy variables for S sectors
R = An index of regulatory strictness
$W_{K,L,E,M}$ = Prices of capital, labor, energy and materials
Q = Plant-level output

Our dataset, described in the following section, combines information from several sources: plant- and sector-level data on emissions and employment from national and regional EPA's; sector-level information on output and employment from national census bureaus and the World Bank's international database (BESD); and data from BESD on national income, population, and

[7] For recent evidence, see Pargal and Wheeler (1996), Wang and Wheeler (1996), and Hettige, et. al. (1997).

[8] Data-gathering in this context is not a simple task. Even assembly of the relatively sparse dataset used for this exercise has required a massive canvass of World Bank project files, consultants' reports, and emissions reports from many national environmental protection institutions. The data are briefly surveyed in the following section, with a more detailed description in the Appendix.

a number of other variables. For cross-country consistency, we use summary data by sector.[9] Plant-level relations between scale (Q) and pollution intensity (P/Q) are not relevant for sectoral aggregates, so we impose the assumption of constant returns ($\alpha_Q = \beta_Q = 1$).[10] This implies estimation of the pollution and labor equations in intensity form, with P/Q and L/Q as the dependent variables.

Using the BESD database, we estimate sectoral average L/Q ratios for each sample country. We construct sectoral average P/L ratios (sectoral pollution intensities w.r.t. labor) from the data provided by national and regional EPA's. We estimate P/Q (pollution intensity w.r.t. output) by multiplying L/Q and P/L for each sector and country. The results permit us to estimate the following equations:

$$\text{(5)} \quad \ln\frac{P_j}{Q_j} = \alpha_0 + \sum_S \delta_{SP} D_{SP} + \alpha_R \ln R_j + \alpha_K \ln W_{K_j} + \alpha_L \ln W_{L_j} + \alpha_E \ln W_{E_j} + \varepsilon_j$$

$$\ln\frac{L_j}{Q_j} = \beta_0 + \sum_S \beta_{SL} D_{SL} + \beta_P \ln R_j + \beta_K \ln W_{K_j} + \beta_L \ln W_{L_j} + \beta_E \ln W_{E_j} + \nu_j$$

In some cases, we have clear prior expectations about parameter signs:

Regulation: Ceteris paribus, we expect stricter regulation to have a negative impact on pollution intensity. We have no clear prior about its impact on labor intensity at the sector level.

Labor Price: We naturally expect increasing wages to reduce the labor intensity of industrial output. The effect of wages on pollution intensity is less transparent. Econometric estimates of KLEM (capital, labor, energy, materials) models has suggested that (K,E) and (L,M)

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[9] See Appendix I for a description of data sources in each country.

[10] Marginal abatement costs decline with treatment scale for most pollutants, because abatement capital is lumpy. Thus, the estimated output elasticity of emissions in a plant-level equation is generally less than one. For evidence from Asia, see Pargal and Wheeler (1996). At the sectoral level, however, the constant-returns assumption seems appropriate for cross-country work. It is possible that characteristic plant scale is larger in countries with greater sectoral output, but we have no way to test this proposition with the available data.

are complements in production, while the pairs KE and LM are gross substitutes.[11] If these relations hold, a wage increase should have the following effects on emissions:

(1) Materials use and the volume of polluting residuals should decline;

(2) Labor use should decrease in both processing and pollution abatement activities, with some increase in pollution from the latter effect. However, our prior expectation is that the materials-reducing effect should dominate: A wage increase should reduce water pollution intensity.

Energy Price: If labor and energy are gross substitutes in production, then an increase in the price of energy should increase the labor intensity of production. In the case of pollution, an energy price increase will reduce energy use for both processing and pollution abatement. Abatement activity should therefore fall, and water pollution intensity should rise.

Capital Price: A capital price increase should also increase labor intensity. For pollution, an increase in the interest rate or the price of equipment should reduce capital and energy use as well as pollution abatement, while increasing the use of labor and materials in processing. Both reduced abatement and increased materials use should lead to more water pollution.

2.3.2 Pollution Intensity and Economic Development

Regulatory strictness and some input prices (e.g., wages) change systematically as per capita income increases. To assess the overall impact of economic development, we also estimate our intensity equations in reduced form:

$$(6)\quad \ln\frac{P_j}{Q_j} = \rho_j = \gamma_0 + \sum_S \delta_{SP} D_{SP} + \rho_y \ln y + \varepsilon_j$$

$$\ln\frac{L_j}{Q_j} = \lambda_j = \gamma_0 + \sum_S \gamma_{SL} D_{SL} + \gamma_y \ln y + \nu_j$$

These equations have two specific roles to play in our analysis. First, they provide an estimate of ρ_y, the elasticity of end-of-pipe pollution intensity with respect to income per capita. We use this to construct the index η in Equation (1). The results also provide estimates of

[5] See Christensen, et al. (1973).

average sectoral pollution intensities (δ_{SP}) across countries. We combine these intensities with our panel data on sector shares by country to construct estimates of $\widetilde{\rho}$ for use in Equation (3).

3. DATA

3.1 Industrial Pollution

To our knowledge, this is the first comparative international study of industrial pollution which uses direct observations on emissions. We have obtained the data from environmental protection agencies in Brazil, China, Finland, India, Indonesia, Korea, Mexico, Netherlands, Philippines, Sri Lanka, Taiwan (China), Thailand and the US. Descriptions of the data sources are provided in Appendix I.

We use the pollution information and complementary employment data to estimate emissions intensities by industry sector in kilograms per day per employee. We focus on organic water pollution because it provides the most plentiful and reliable source of comparable cross-country emissions information. Water pollution data are the most plentiful because developing countries have traditionally begun industrial pollution control programs with regulation of organic water emissions. They are relatively reliable because sampling techniques for measuring water pollution are more widely understood and much less expensive than those for air pollution.

3.2 Environmental Regulation

Some comparable measure of regulatory strictness is necessary for estimation of our cross-country equations. However, credible indices of environmental regulation are difficult to find. Even in the US, comparative analyses of state-level regulatory 'outputs' have generally used input-based measures such as expenditures on monitoring and enforcement, or total employment of inspectors.[12] Such measures may have at least some justification for within-country analyses, since quality- and price-adjustment problems are not too serious. For international comparisons, however, they would be problematic even if comparable data were available. Most developing countries do not have such data, so input-based comparisons are not possible in any case.

A more promising approach has been taken by recent econometric work on the sources of variation in regulatory strictness. This work is helping to identify robust proxies which can be used as instruments in cross-country comparisons. The best instrument is undoubtedly per capita income, which has been shown to affect both formal and informal regulatory pressure on polluters in the US and Asia (McConnell (1992), Pargal and Wheeler (1996), Hartman, et. al. (1997), Hettige, et. al. (1996) and Wang and Wheeler (1996)). Dasgupta et. al. (1995) have advanced the state of the art by developing quantitative indices of regulatory development from reports filed for the U.N. Conference on Environment and Development (UNCED - Rio de Janeiro, 1992). Their results suggest that international differences in pollution regulation are well-explained by a model which incorporates the effects of per capita income, urbanization, population density, and manufacturing share in national output. We have adopted the Dasgupta model to produce a cross-country pollution regulation index for this paper. Six of our thirteen country cases have actually been scored by the Dasgupta exercise. For the remaining seven cases, we have calculated the pollution regulation index values using the Dasgupta equation.

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[12] See for example Levinson (1994) and Beede (1993).

3.3 Input prices

We have computed wages (in $US 1990 per worker) by ISIC sector from UNIDO's reported sectoral totals for employment and payrolls. Our electricity tariff rates for the OECD and developing countries have been drawn from International Energy Agency data and the World Bank's Power Sheets database, respectively. The World Bank's World Development Indicators database has provided our national real interest rate measures.

3.4 Employment, Income and Output

Estimation of equations (2), (3), (5) and (6) requires cross-country data on total output, industrial output, employment, income, population and a number of other variables. We have obtained the relevant panel data from the World Bank's international database (BESD). We have used Summers-Heston estimates as our measure of income per capita.

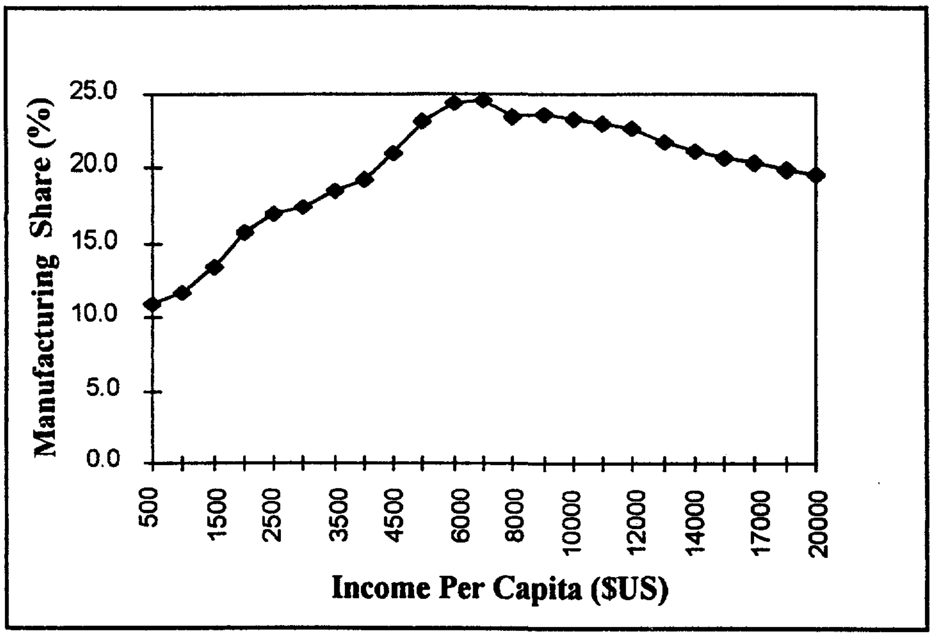
4. ECONOMETRIC RESULTS

4.1 Manufacturing Share in National Output

Table 4.1 reports panel estimates for equation (2). We provide comparable results for OLS, fixed-effects (without time dummies) and random effects models. We prefer the random effects model, but the choice of estimator does not have a major effect on the results. They are consistent with an inverted-U model for manufacturing share in national output. Our results also suggest some structural change in the relationship, since the interactions of time with income and income squared both satisfy classical significance criteria. During the past two decades, the 'inverted-U' appears to have steepened somewhat and shifted downward.

To illustrate the implied relationship, we have calculated median manufacturing shares by income class for all 1,717 observations in our sample. The result (Figure 4.1) suggests that manufacturing share rises steeply with income until a country reaches middle-income status;[13] from around 10% in countries with less than $1000 per capita (Summers-Heston income, in $US 1990) to around 25% in countries with incomes of $5,000-$6,000. Then the manufacturing share slowly declines to around 20% in countries with $20,000 or more.

Figure 4.1: Manufacturing Share in GDP vs. Per Capita Income, 1975-1994



4.2 Changes in Sectoral Composition

Table 4.2 reports results for our analysis of changes in sectoral composition. We have employed panel techniques to estimate Equation (3) in log-log form, using the log of share-weighted average BOD intensity as the dependent variable. Again, the fixed-effects and random-effects estimates tell the same story: As income per capita increases, overall pollution intensity declines because relatively 'clean' sectors grow more quickly. However, our results suggest that

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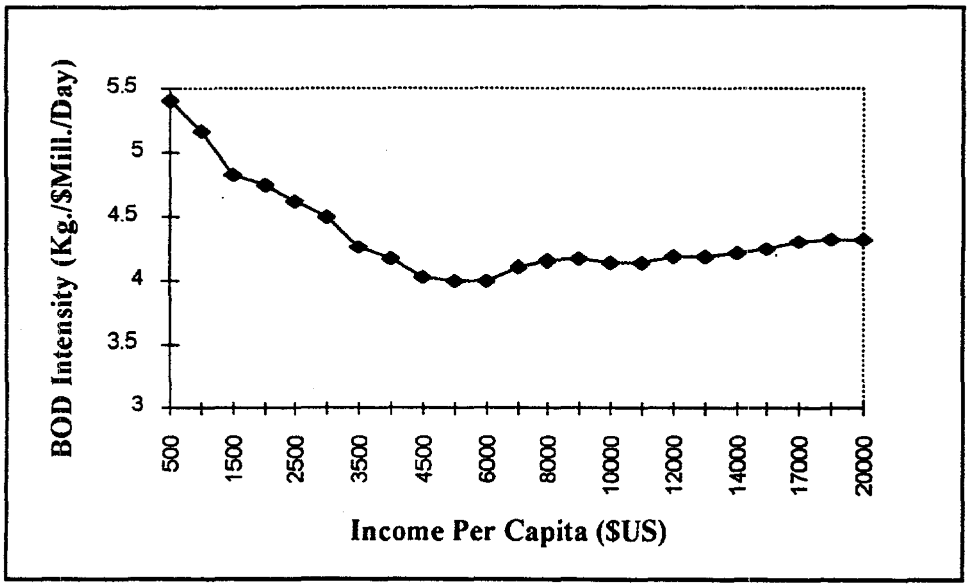
[13] We have smoothed the series with a three-interval moving average: Each share observation on the graph is the average for the previous, corresponding, and succeeding income groups.

the rate of decline also decreases. We find no evidence of a structural change, except for a very slight (but significant) upshift in compositional pollution intensity.

In Figure 4.2, we provide an illustration of the relationship between overall pollution intensity and income during the sample period.[14] The figure is based on median values of overall intensity for each income group in the set of 2,210 observations. It suggests that sector-weighted average water pollution intensity declines from nearly 6 Kg. to 4Kg. Per $US 1 million per day, or about 30%, as income increases to around $5,000 per capita. Then it remains approximately stable over the higher-income range.

Figure 4.2 Industrial BOD Intensity vs. Income Per Capita



[14] We have also used three-interval smoothing for Figure 4.2. See Footnote 13.

4.3 End-of-Pipe Pollution Intensity

Tables 4.3 - 4.5 report cross-country regression results for Equations (5) and (6). We use dummy variables to control for sectoral differences in average pollution intensity; dummy variable controls are also introduced for national differences in reporting procedures and measures of organic water pollution. The majority of environmental protection agencies (EPA's) have reported emissions of biological oxygen demand (BOD), which is a measure of oxygen removal from water by bacteria which are oxidizing organic materials. However, three EPA's – for China, Netherlands and Taiwan (China) – have reported COD (chemical oxygen demand). COD incorporates the effect of other pollutants on the rate of oxidization; it is systematically larger than BOD measures.

We have controlled for the measurement problem by introducing a dummy variable for COD-based emissions reports. As expected, the estimated COD dummy is positive, large and highly significant in all pollution intensity equations. Our sectoral dummy variable results are also in accord with prior expectations: Food and Paper have the highest average organic water pollution intensities; Metals and Mineral Products have the lowest. In the case of labor intensity, Textiles, Food and Wood Products are highest (along with Other Manufacturing, the numeraire sector); Metals and Chemicals are the lowest.

We have also controlled for the possible impact of differences in emissions reporting procedures. In several cases (China, India, Indonesia, Netherlands, Philippines, Sri Lanka, Taiwan (China), Thailand) the plant-level information provided by the EPA's includes employment data. This has enabled us to estimate sectoral pollution/labor ratios directly from the EPA data. In the other cases (Brazil, Finland, Korea, Mexico and the US), the EPA's have provided summary pollution data by sector. We have obtained summary employment data by sector from other national or regional sources, and have used the two summaries to calculate sectoral pollution/labor ratios.

We recognize the possibility of systematic differences in the results generated by these two approaches. EPA's in developing countries focus on large polluters, so the average pollution intensity of these facilities will be reflected in estimates based on plant samples. The situation is potentially quite different when EPA-reported sectoral emissions are divided by census-reported sectoral employment. Plants which ignore pollution regulations (and whose reported pollution is therefore zero) may nevertheless be registered in an employment census. This might impart a downward bias to summary-based intensities. In addition, all five countries for which we employ summary data (Brazil, Finland, Korea, Mexico, US) are in the middle or high income category. Thus, failure to control for the sampling difference might also produce a downward bias in the estimated effect of income or wages on pollution intensity.

We have introduced a dummy variable to control for this difference, but it is not significant in our regressions. In fact, we are not overly surprised by this result because effective coverage of industrial facilities by both census-takers and regulators is a function of development.[15]

4.3.1 The Effects of Pollution Regulation and Relative Input Prices

As expected, the estimated wage-elasticity of labor intensity is large (around -.70) and highly significant. The wage elasticity of pollution intensity is also negative, large (-1.71) and highly significant. In the pollution intensity equation, our results are consistent with the hypothesis that

[15] Both approaches may underestimate 'true' sectoral pollution intensities in developing countries, because existing research suggests that medium and large plants have lower pollution per unit of output than smaller facilities (ceteris paribus). Since smaller plants are covered by regulators in developed economies, our econometric result may actually understate the effect of income on pollution intensity. We accept the plausibility of this hypothesis, but we have no way to test it at present.

labor and pollution are complements in production. However, the converse is not true. Our index of regulatory strictness is not significant in the labor intensity equation.

While the latter result is not particularly surprising, we also find that our regulatory strictness index is not significant in pollution intensity regressions which control for wages. Does this imply that market forces alone drive pollution, and that regulation is irrelevant? Although our results are consistent with this interpretation, we reject it for several reasons. First, our wage and regulation variables are highly collinear because they are both correlated with per capita income. As Table 4.4 shows, each variable is significant in equations which exclude the other. Second, a large body of empirical work suggests that industrial pollution is responsive to pressure from local communities (Pargal and Wheeler, 1996; Hettige, et. al., 1997, Hartman, et. al., 1996), as well as formal regulation. Both forms of regulation are strongly affected by income, reflecting increasing preferences for environmental quality and higher valuation of pollution damage. We believe that the estimated wage elasticity in our pollution intensity regression is capturing cross-country income effects on formal and informal regulation, as well as the effect of complementarity with pollution in production. With currently-available information, we cannot distinguish clearly between these two effects. However, their joint effect clearly shows the impact of rising income on pollution intensity.

Our results for energy and capital prices are considerably weaker. Surprisingly, neither variable is significant in the labor intensity equation when both are included. In the pollution intensity regression, the estimated electricity price elasticity is positive, large and highly significant. The real interest rate elasticity is also positive, and close to significance at the 5% level. However, these results are not robust to changes in right-hand variables or sample composition. Dropping the real interest rate increases the sample size, because we do not have real interest rate data for Mexico, Brazil and Taiwan (China). However, with the larger sample the electricity price elasticity loses significance in the pollution intensity equation, while becoming large, *negative*, and highly 'significant' in the labor intensity equation. We conclude that our results for capital and energy prices are highly sensitive to outliers, and we see no reason to draw any clear conclusions from our results.

4.3.2 Economic Development and Pollution Intensity

We have also estimated reduced-form intensity equations which control for per capita income, sector and COD reporting. The results are summarized in Table 4.5 for three intensities: labor/output, pollution/output and pollution/labor. In all three equations, the results for the sectoral dummies replicate the pattern of results in Tables 4.3-4.4. As before, the dummy variable for COD is positive and significant in the pollution equations.

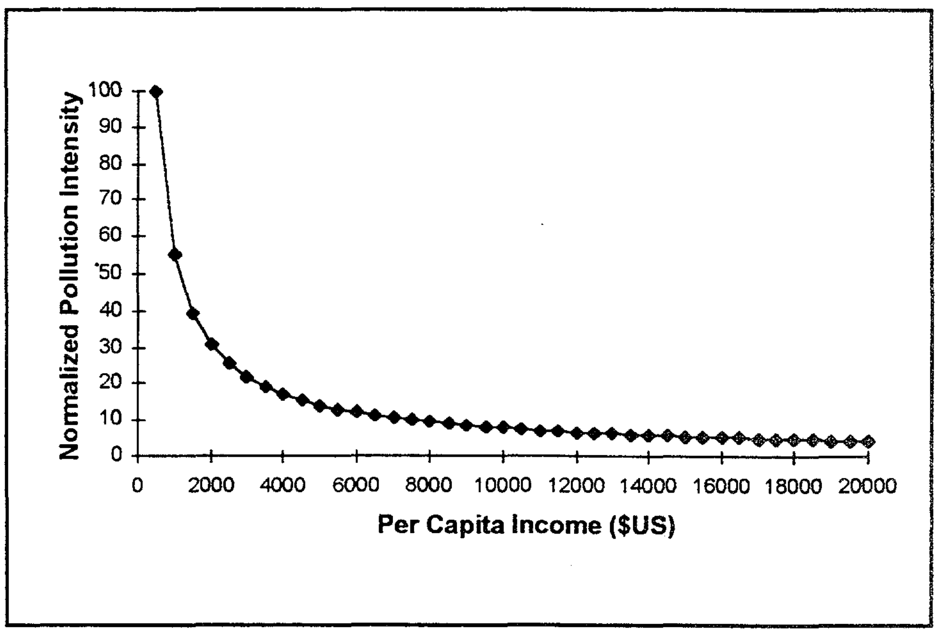
The results for per capita income suggest a striking regularity across countries. The income elasticities of pollution/output and labor/output are both negative, and not significantly different from one. In the third equation, we test for the equality of pollution and labor elasticities (w.r.t. income) by regressing pollution/labor on the same set of right-hand variables (this amounts to differencing the coefficients in the first two equations). *The resulting elasticity of pollution/labor with respect to income per capita is not significantly different from zero.* Of course, we cannot generalize from one sample for one pollutant to all industrial emissions. However, *for industrial water pollution, our results suggest that sectoral emissions/labor ratios are approximately constant across countries at all income levels.* Developing economies generate much more pollution per unit of output than developed economies, but they also employ much more labor per unit of output, and in the same proportion.

Figure 4.3 and Table 4.6 portray the estimated relationship between pollution intensity (per unit of output) and income per capita. For ease of interpretation, we normalize to an intensity value of 100 for the poorest income category ($500 per capita). The cross-country evidence suggests a sharp drop in pollution intensity with income growth, as manufacturers respond to higher wages and regulatory pressures with end-of-pipe abatement and process change. From an emissions index value of 100 at $500 per capita, pollution abatement is about 60% at $1,500, 80% at $3,000, 90% at $7,000 and 95% at $15,000.

Table 4.6: Income and Pollution Abatement

Income Per Capita	% Abatement
1,500	60
3,000	80
7,000	90
15,000	95

Figure 4.3: Water Pollution Intensity vs. Income Per Capita



5. IMPLICATIONS OF THE RESULTS

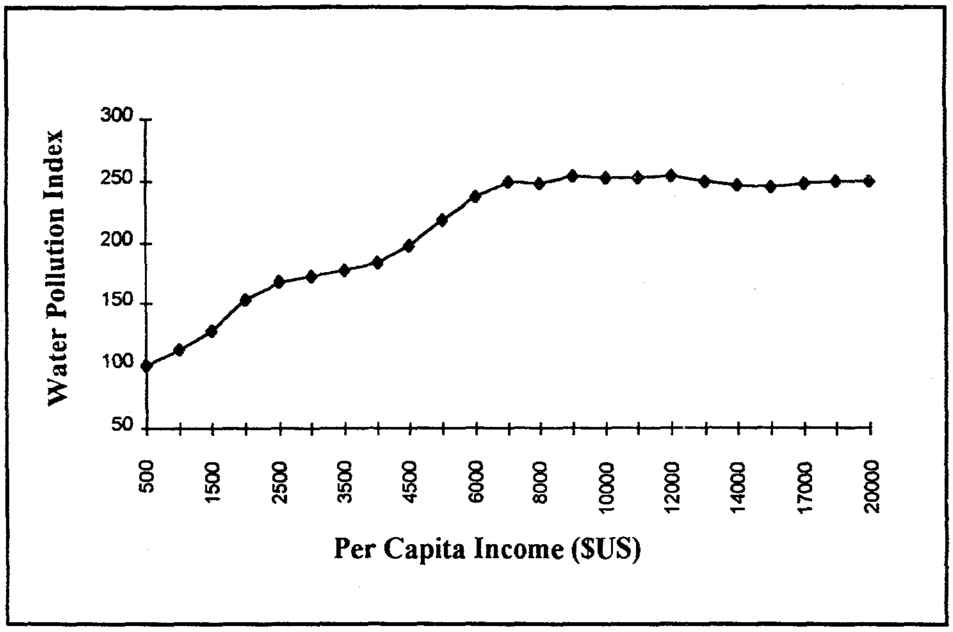
5.1 The Kuznets Hypothesis

Our estimation exercises have suggested three distinct patterns of response to economic development. Industry's share of national output rises sharply through middle-income status and then slowly declines. Sectoral composition follows a 'clean' trend for low-income developing countries, but exhibits little or no trend beyond the middle income range. End-of-pipe pollution intensity, by contrast, declines continuously with income.

We use simulation to project the net result of changes in these three factors. Our four simulation variables are in columns 1-4 of Table 5.1. Column 1 includes a broad range of incomes, from $US 500 to $US 20,000 per capita. Columns 2 and 3 replicate the information on manufacturing output shares and average pollution intensities in Figures 4.1 and 4.2. Column 4 reproduces the pollution intensity index in Figure 4.3, re-normalized to one for the lowest income level.

We assume a unit population for convenience, so income per capita also serves as a measure of total output. We simulate the overall relationship between economic development and industrial pollution by multiplying the four column entries in each row. The result combines the effects of changes in total output, manufacturing share, sectoral composition, and end-of-pipe pollution intensity. Column 5 and Figure 5.1 portray the total pollution estimate, which has been normalized to an index value of 100 at the lowest income level. Our result suggests that the inverted U-shaped story is only half right for industrial water pollution: Total emissions rise sharply in the range [$500 - $7,000], but remain constant as income increases further.

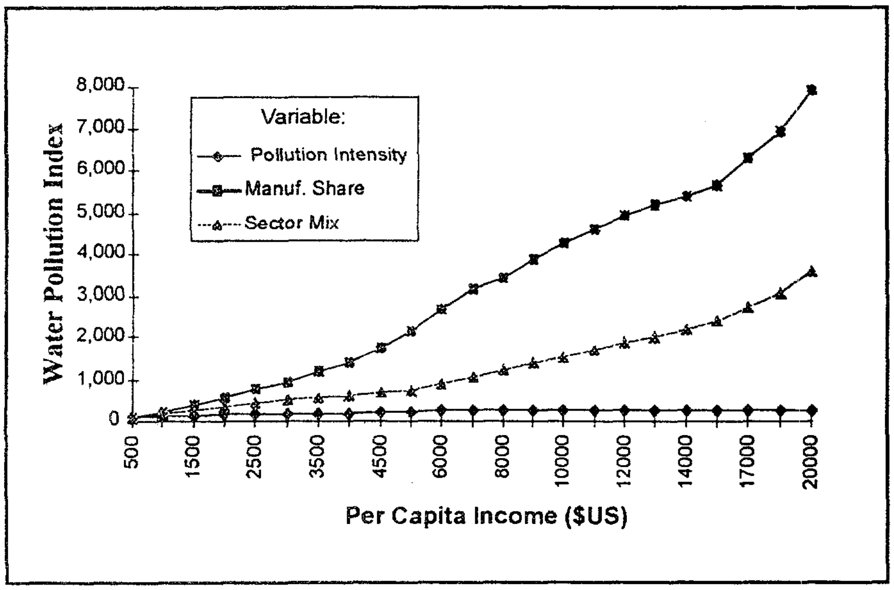
Figure 5.1 Industrial Pollution and Economic Development



To assess the contribution of each factor to the overall result, we perform three counterfactual simulations which are tabulated in columns 6-8 and illustrated in Figure 5.2 Each simulation allows one of columns 2-4 to vary while holding the other two constant at the lowest-income level. The experiment in column 6 holds sectoral composition and end-of-pipe pollution intensity constant, while allowing the share of manufacturing to vary with income. The result is rapid growth of pollution over the whole income range, and an estimated pollution load at $20,000 which is eighty times the initial load. To produce column 7, we allow sectoral composition to vary while holding the other two factors constant. Pollution growth is considerably moderated by comparison with column 6, but the projected load at $20,000 is still 40 times the initial load. Finally, we test the effect of end-of-pipe change in column 8. This experiment clearly identifies the most important factor: Projected emissions at $20,000 are only 1.8 times the initial load, if manufacturing share and sectoral composition are held constant.

We conclude that pollution levels off in the middle income range because end-of-pipe pollution intensity responds to rising wages and stricter regulation. By comparison, the manufacturing share and sectoral composition are minor players. For industrial water pollution, the inverted-U pattern does not emerge because declining pollution intensity almost exactly balances output growth, while manufacturing share and sectoral composition remain constant beyond the middle income range.

Figure 5.2: Counterfactual Simulations



5.2 Trends in International Emissions

To explore the real-world implications of our results, we estimate pollution loads for a set of large industrial economies during the period 1977 - 1989. Powerful leverage is provided by our finding that sectoral pollution per unit of labor (P/L) remains approximately constant across the entire range of incomes. This allows us to use commonly-available sectoral labor/output (L/Q) ratios to predict international changes in industrial water pollution. As an illustration, we use the World Bank's BESD database to estimate sectoral L/Q ratios for fifteen countries during the period 1977-1989. To estimate BOD loads by sector, we multiply the L/Q ratios by sectoral P/L coefficients calculated from our regression results for P/L.[16]

We have chosen the fifteen countries to represent large industrial economies in four major groups: OECD (represented by the US, Japan, France and Germany (former F.R.); the NIC's (Mexico, Brazil, Taiwan, Korea, South Africa, Turkey); Asian LDC's (China, India, Indonesia); and the ex-COMECON countries (Poland, former USSR). The results are tabulated in Table 5.3 (Appendix II) and summarized in Table 5.2 below. Taken together, they illustrate the main implications of our empirical analysis.

In the OECD, despite modest continued economic growth, estimated BOD emissions remain almost constant. In our view, this reflects the countervailing effects of output growth and increases in wages and regulation; manufacturing shares and the 'clean' sector share change very little. The COMECON economies are in relative stagnation during the sample period, so there is little movement in their estimated emissions.

The story for the NIC's is quite different. Their estimated pollution increases by about 25% during the sample period – substantially less than their growth in per capita income. The increase is relatively moderate because rapid output growth is offset by three factors: the negative impact of increased wages and regulation on industrial pollution intensity; the first stage of the decline in manufacturing share; and the last stage of the 'clean' trend in sectoral composition.

The Asian LDC experience is also distinctive. Estimated BOD emissions grow by approximately 55% in these lower-income economies, because rapid output growth and

[16] For this application, we regress log (P/L) on dummy variables for COD and the industry sectors. Since income is insignificant, we impose a parameter value of zero by dropping it from the equation. To calculate sectoral P/L ratios, we assume the BOD case (COD=0), add the constant term to the estimated parameters for the sector dummies, and calculate the antilogs of the results.

increasing manufacturing share dominate the clean compositional trend and the first effects of rising wages and regulation on pollution intensity. To a striking degree, BOD growth in our international sample is due to increased emissions in developing Asia.

The overall result of these changes is a significant shift in group shares of total pollution. Table 5.2 shows that the OECD and COMECON countries drop significantly in share; the NIC's increase marginally; and the Asian LDC's jump from 29% to 37% of the total. Equally impressive, however, is the apparently moderate growth in total BOD emissions during the period when world concern over environmental damage was reaching a peak. While economic development was sparking greater interest in pollution, is was also setting the stage for real improvements in environmental performance. From 1977 to 1989, we estimate that total industrial BOD emissions grew by only 16% in these fifteen major industrial countries.

Table 5.2: Trends in International Emissions: Selected Countries, 1977 - 1989

	BOD Emissions ('000 Kg./Day)				
Region	**1977**	**1980**	**1983**	**1986**	**1989**
OECD	5,776	5,847	5,501	5,403	5,523
NIC's	1,565	1,917	1,848	2,197	2,188
ASIAN LDC'S	4,617	5,030	5,566	6,183	6,883
COMECON	4,127	4,218	4,302	4,228	4,039
TOTAL	**16,085**	**17,012**	**17,217**	**18,011**	**18,633**
	% of Sample Total				
	1977	**1980**	**1983**	**1986**	**1989**
OECD	36	34	32	30	30
NIC's	10	11	11	12	12
ASIAN LDC'S	29	30	32	34	37
COMECON	26	25	25	23	22
TOTAL	100	100	100	100	100

6. SUMMARY AND CONCLUSIONS

In this paper, we have used new international data to investigate the relationship between industrial pollution and economic development. To test for a Kuznets effect, we measure the effect of income growth on three proximate determinants of pollution: The share of manufacturing in total output; the sectoral composition of manufacturing; and the intensity (per unit of output) of industrial pollution at the end-of-pipe. We find that the manufacturing share follows a Kuznets-type trajectory, but the other two determinants do not. Sectoral composition gets 'cleaner' through middle-income status and then stabilizes. At the end-of-pipe, pollution intensity declines strongly with income. We attribute part of this to stricter regulation as income increases, and partly to pollution-labor complementarity in production.

Our results suggest that income elasticities of both pollution- and labor-intensity are approximately minus one. The remarkable implication is that ***a sector's pollution/labor ratio is constant across countries at all income levels***. Our findings motivate two illustrative simulation exercises. First, for a set of income benchmarks, we simulate total pollution by combining representative measures of manufacturing share in output, sectoral composition, and end-of-pipe pollution abatement. We do not see a Kuznets-type story in the result, since total pollution rises rapidly through middle-income status and remains approximately constant thereafter. In three counterfactual experiments, we assess the relative importance of the three proximate determinants. Our results highlight the dominance of end-of-pipe reductions as wages and regulation increase with development. The combined influence of changes in manufacturing share and sectoral composition is lower by almost two orders of magnitude.

Our second simulation uses international panel data to explore the implications of constant sectoral pollution/labor ratios. We estimate recent trends in water pollution for fifteen major industrial nations in the OECD, the NIC's, Asian LDC's and the ex-COMECON economies. We find approximately stable emissions in the OECD and ex-COMECON, moderate increases in the NIC's and rapidly-growing pollution in the Asian LDC's. During the 1980's, our estimates suggest that the latter group displaced the major OECD economies as the world's largest generator of organic water pollution. Overall, however, the negative feedback from economic development to pollution intensity was sufficient to hold total world pollution growth to around 15% during a twelve-year sample period.

In closing, it is worth asking whether these results are cause for optimism or pessimism. The appropriate answer seems to be 'both.' It is comforting to see that industrial water emissions level off in richer economies because pollution intensity has an elastic response to income growth. Unfortunately, unitary elasticity implies that total emissions remain constant unless other factors intervene. Of course, industry tends to deconcentrate over time as infrastructure improves and prosperity spreads. Constant total emissions may therefore be consistent with improving water quality in at least some areas. However, the continued existence of many seriously-polluted waterways, even in the most prosperous countries, suggests that economic development remains far short of a Kuznets-style happy ending in the water sector.

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Appendix I: DATA SOURCES

Brazil: The water pollution data for the Sao Paulo Metropolitan region of Brazil were collected by CETESB, the environmental agency for Sao Paulo State. Our pollution estimates are based on CETESB's 1250-plant database, which includes measures of BOD loads in kg/day. The corresponding employment data came from the Sao Paulo State Ministry of Labor, which provided 2-digit sectoral information from 1991 on nearly 41,000 plants and 2.15 million workers.

China: Water pollution data for China were obtained from the National Environmental Protection Agency (NEPA), which maintains a comprehensive database on major sources of industrial pollution in China. Our estimates are based on NEPA's 1993 emissions data for 269 factories scattered throughout China.

Finland: The Finnish economic data, aggregated at the 3-digit ISIC level, were provided by the Central Statistical Office, covering both white and blue collar workers for 1989. The pollution data were provided by the Industrial Waste Water Office of the National Board of Waters and the Environment. They cover water emissions in 1992 from 193 large water-polluting factories.

India: The India data are from the state of Tamil Nadu. Plant-level pollution data and employment data for 1993-94 were provided by the Tamil Nadu Pollution Control Board, which monitors air and water pollution for all the manufacturing units in the state.

Indonesia: The Indonesia data came from two different sources. The plant-level emissions data were provided by BAPEDAL, Indonesia's National Pollution Control Agency in the Ministry of Environment. The economic data are from Indonesia's Central Statistics Bureau (BPS).

Korea: Korean pollution data were provided by the National Pollution Control Agency. They cover water emissions by 13,504 facilities in 1991. Complementary employment data have been drawn from Korea's National Statistical Yearbooks and the ILO's **International Labor Statistics**, 1991.

Mexico: Data for water emissions in the Monterrey Metropolitan Area were provided by the State Water Monitoring Authority. The data cover emissions from 7,500 facilities in 1994. Complementary employment data were provided by Mexico's Census Bureau (INEGI).

Netherlands: Water emissions and employment data for approximately 700 regularly-monitored facilities in 1990 were provided by the Emissions Inventory System maintained by the Ministry of Housing, Spatial Planning and the Environment (VROM).

Philippines: Water emissions and employment data for factories in the Metro Manila Area (MMA) were provided the Philippines Department of Natural Resources (DENR) and the Laguna Lake Development Authority.

Taiwan (China): Water emissions and employment data for 1,800 plants were provided by the Water Quality Protection division of the Taiwan Environment Protection Agency.

Thailand: Seatec International, a private-sector environmental consulting firm in Bangkok, provided plant-level data from two industrial estates in Rangsit and Suksawat. The dataset contained information on water emissions and employment for approximately 450 facilities in 1992.

Sri Lanka: Water pollution and employment data for Sri Lanka were obtained from a study of waste water treatment options for the Ekala/Ja-ela Industrial Estate, which includes 143 industrial establishments with 21,000 employees. The data were collected by a joint project of the World Bank's Metropolitan Environment Improvement Program and the Sri Lankan Board of Investment. Ekala/Ja-Ela industrial estate is one of the two major industrial estates in Sri Lanka.

U.S.A.: The information for the United States were drawn from two main sources. The water emissions data have been collected from regional databases which monitor industrial water discharges as part of the U.S. Environmental Protection Agency's NPDES system. Employment data are from the U.S. Census Bureau's Longitudinal Research Database.

Appendix II: Tables

Table 4.1: Log (Manufacturing Share of Total Output) vs. Log (Income Per Capita), 1975-1994*

Independent Variables	OLS	Fixed Effects	Random Effects	OLS	Fixed Effects	Random Effects
Log Income	0.9195 (2.483)	0.5147 (1.815)	0.5726 (2.076)	1.3585 (7.934)	0.7719 (6.815)	0.9402 (8.323)
Log Income squared	-0.0442 -(1.796)	-0.04268 -(2.185)	-0.0364 -(1.923)	-0.0704 -(6.446)	- 0.05988 -(8.772)	-0.0622 -(8.988)
Log Income * Time	0.07527 (1.993)	0.0450 (3.126)	0.0511 (3.456)	***	***	***
Log Income squared * Time	-0.0045 -(1.858)	-0.0028 -(3.154)	-0.0032 -(3.538)	***	***	***
Time	-0.3194 -(2.196)	-0.1614 -(2.762)	-0.1911 -(3.205)	-0.0120 -(4.224)	0.0146 (6.612)	0.0062 (3.190)
Constant	-6.1460 -(4.480)	-3.3256 -(3.254)	-4.074 -(4.095)	-7.9373 -(12.013)	-4.2714 -(8.897)	-5.3585 -(11.415)
Number of Observations	1136	1136	1136	1136	1136	1136
Number of Time Periods	16	16	16	16	16	16
Adjusted R-squared	0.299	0.151	0.015	0.297	0.171	0.003

* T-statistics in parentheses

Table 4.2: Log (Sector-Weighted BOD Intensity) vs. Log (Income Per Capita), 1975-1994*

Independent Variables	OLS	Fixed Effects	Random Effects	OLS	Fixed Effects	Random Effects
Log Income	0.2846 (1.018)	-0.3903 -(3.566)	-0.3709 -(3.427)	-0.0236 -(0.184)	-0.5362 -(12.719)	-0.5283 -(12.616)
Log Income squared	-0.0234 -(1.321)	0.01749 (2.459)	0.0164 (2.344)	-0.0019 -(0.249)	0.0269 (11.050)	0.0267 (10.974)
Log Income * Time	-0.0117 -(0.416)	-0.00736 -(1.214)	-0.0071 -(1.171)	***	***	***
Log Income squared * Time	0.0009 (0.578)	0.0005 (1.398)	0.0004 (1.374)	***	***	***
Time	0.03203 (0.278)	0.0319 (1.232)	0.0300 (1.161)	0.0034 (2.166)	0.0055 (6.402)	0.0051 (6.351)
Constant	0.6935 (0.633)	3.4369 (8.168)	3.3470 (8.035)	1.7679 (3.373)	3.9912 (21.143)	3.9435 (20.989)
Number of Observations	928	928	928	928	928	928
Number of Time Periods	16	16	16	16	16	16
Adjusted R-squared	0.043	0.043	0.043	0.043	0.041	0.041

* T-statistics in parentheses

Table 4.3: Intensity Equations for Pollution and Labor (in Prices and Regulation)

Dep. Var. – Log. of:	Pollution/ Output		Pollution/ Output		Labor/ Output		Labor/ Output	
Independent Variables	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**
Log Wage	-1.714	-3.055**	-0.015	-0.044	-0.711	-8.473**	-0.379	-6.380**
Log Brown Index	2.459	0.958	-2.995	-1.601	0.164	0.422	-1.467	-4.657**
Log Electricity Price	6.123	3.684**	0.620	0.526	-0.098	-0.580	-0.564	-3.354**
Log Real Interest Rate	0.455	1.903*			0.029	0.872		
COD	4.308	4.829**	2.406	2.559**				
Food	5.658	5.044**	4.511	3.940**	-0.571	-3.817**	-0.813	-4.239**
Textiles	4.601	4.163**	3.932	3.449**	-0.018	-0.125	-0.168	-0.881
Wood Products	3.717	2.775**	3.103	2.176**	-0.021	-0.140	0.053	0.280
Paper	6.864	6.102**	4.946	4.318**	-0.151	-1.006	-0.231	-1.205
Chemicals	4.614	3.916**	3.236	2.785**	-0.526	-3.320**	-0.715	-3.669**
Non-Metallic Minerals	1.290	1.118	1.023	0.879	-0.123	-0.823	-0.242	-1.263
Metals	2.312	1.910*	0.988	0.828	-0.697	-4.383**	-0.771	-3.903**
Metal Products	3.538	3.063**	2.232	1.920*	-0.278	-1.842*	-0.502	-2.612**
Constant	-27.244	-2.466**	-0.702	-0.096	-5.253	-3.162**	1.933	1.479
Adjusted R-square		0.63		0.34		0.92		0.81
Number of Observations		68		99		80		116

*** significant at 1% confidence level
** significant at 5% confidence level
* significant at 10% confidence level

Table 4.4: Intensity Equations for Pollution and Labor (in Prices and Regulation)

Dep. Var. – Log of:	Pollution/ Output		Labor/ Output		Pollution/ Output		Labor/ Output	
Independent Variables	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**
Log Wage	-1.211	-6.153	-0.666	-22.600				
Log Brown index					-4.885	-5.052	-2.872	-14.642
Log Electricity Price	5.634	3.565	-0.280	-1.223	3.765	2.384	-1.173	-3.871
Log Real Interest Rate	0.370	1.668	0.025	0.807	0.234	0.957	-0.058	-1.27
COD	4.375	4.923	-0.110	-0.852	4.125	4.32	-0.197	-1.071
Food	5.485	4.959	-0.585	-3.979	5.073	4.278	-0.792	-3.767
Textiles	4.586	4.153	-0.018	-0.124	4.556	3.842	-0.016	-0.074
Wood Products	3.654	2.733	-0.028	-0.188	3.429	2.392	-0.131	-0.622
Paper	6.675	6.032	-0.167	-1.132	6.222	5.247	-0.396	-1.882
Chemicals	4.246	3.815	-0.558	-3.764	3.364	2.837	-1.023	-4.866
Non-Metallic Minerals	1.114	0.979	-0.138	-0.941	0.681	0.558	-0.362	-1.720
Metal s	2.014	1.723	-0.722	-4.729	1.243	0.999	-1.094	-5.045
Metal Products	3.323	2.935	-0.296	-2.011	2.784	2.299	-0.560	-2.661
Constant	-16.903	-7.208	-4.403	-13.734	3.324	0.661	7.522	7.83
Adjusted R-square	0.64		0.93		0.59		0.85	
Number of Observations	68		80		68		80	

Table 4.5: Intensity Equations for Pollution and Labor (in Income Per Capita)

Dep. Var. – Log of:	Pollution/Output		Labor/Output		Pollution/Labor	
Independent variables	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
Log Income	-0.875	-3.26**	-1.003	-17.041**	0.120	0.449
COD	1.908	2.542**			1.930	2.576**
Food	4.629	4.096**	-0.925	-4.085**	5.492	4.868**
Textiles	4.055	3.588**	-0.150	-0.662	4.143	3.673**
Wood Products	3.315	2.350**	0.047	0.206	3.485	2.475**
Paper	5.064	4.481**	-0.350	-1.547	5.353	4.745**
chemical	3.349	2.963**	-0.957	-4.225**	4.244	3.762**
mineral	1.151	1.003	-0.361	-1.595	1.414	1.235
metal	1.119	0.962	-0.964	-4.171**	2.038	1.786
metal products	2.367	2.071**	-0.635	-2.803**	2.983	2.615**
constant	-8.872	-3.615**	-1.497	-2.828**	-7.246	-2.972**
Adjusted R-square		0.35		0.74		0.39
Number of Observations		99		116		100

Table 5.1: Industrial Pollution and Economic Development:
Simulation Experiments

Income ($US)	Manuf. Share	BOD Intens.	EOP Intens.	Total BOD	Variable Share	Variable BOD	Variable EOP
500	11.0	5.4	1.00	100	100	100	100
1,500	13.4	4.8	0.39	128	366	268	118
2,500	16.9	4.6	0.25	167	771	428	127
3,500	18.5	4.3	0.19	177	1,179	553	133
4,500	21.0	4.0	0.15	197	1,726	670	138
6,000	24.3	4.0	0.12	237	2,663	888	144
8,000	23.5	4.2	0.09	247	3,424	1,230	150
10,000	23.3	4.1	0.08	253	4,256	1,531	155
12,000	22.6	4.2	0.07	255	4,953	1,859	160
14,000	21.2	4.2	0.06	246	5,399	2,188	163
17,000	20.3	4.3	0.05	248	6,298	2,709	168
20,000	19.5	4.3	0.04	249	7,904	3,559	175

Table 5.3: Estimated Industrial BOD Emissions
Selected Countries, 1977 - 1989 ('000 Kg./Day)

COUNTRY	1977	1980	1983	1986	1989
UNITED STATES	2,652	2,743	2,551	2,454	2,564
FRANCE	739	716	683	666	652
GERMANY (FORMER FR)	929	932	800	789	800
JAPAN	1,456	1,456	1,467	1,493	1,507
OECD	**5,776**	**5,847**	**5,501**	**5,403**	**5,523**
BRAZIL	611	867	771	965	914
MEXICO	109	131	130	179	174
KOREA, REPUBLIC OF	261	282	296	345	377
TAIWAN, CHINA	208	239	252	296	282
SOUTH AFRICA	226	238	245	245	262
TURKEY	150	160	155	167	179
NIC's	**1,565**	**1,917**	**1,848**	**2,197**	**2,188**
CHINA	3,118	3,358	3,957	4,551	5,023
INDIA	1,309	1,457	1,380	1,277	1,428
INDONESIA	190	214	230	355	433
DEVELOPING ASIA	**4,617**	**5,030**	**5,566**	**6,183**	**6,883**
POLAND	578	581	546	484	459
U.S.S.R., FORMER	3,549	3,638	3,756	3,744	3,580
EX-COMECON	4,127	4,218	4,302	4,228	4,039
TOTAL	**16,085**	**17,012**	**17,217**	**18,011**	**18,633**

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